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Effect of laser heat treatment on structure and wear resistance of cobalt stellite

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Abstract. The structure and wear resistance of Stellite 6 alloy were studied before and after laser heat treatment. A significant refinement of the microstructure after the heat treatment is noted, the hardness the alloy changed slightly. An increase of wear resistance in shock-abrasive wear at angles of attack of 60-90° as well as metal-to-metal wear with presence of an abrasive layer is shown.

1. Introduction

In this article the question of the effect of laser heat treatment on the microstructure and wear resistance of cobalt stellite is considered. Laser heat treatment (LHT) is a modern metal surface modification method which can significantly increase the wear resistance and service life of parts.

The work [1] shows that depending on the desired result, 2 modes of Fe-C system alloys processing are used: with and without surface melting. The only possible mode for cobalt stellite processing is the one with surface melting, because the alloy structure does not undergo any significant changes without it.

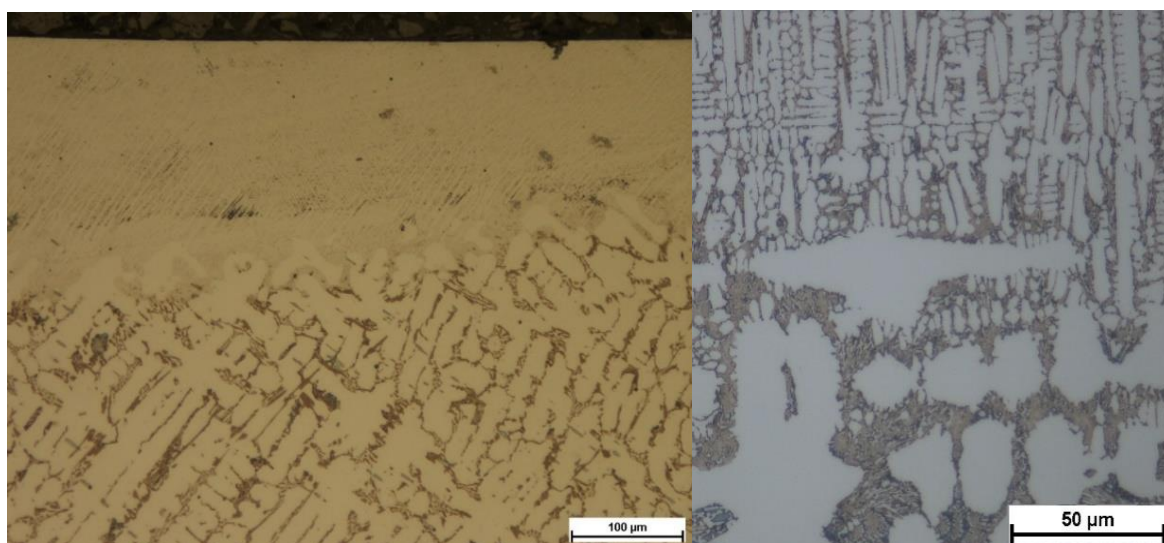


Figure 1. The surface layer microstructure of Stellite 6 alloy after LHT.



The surface processing was performed using laser machine IPG IRE-Polyus LS-5. The power of laser beam was 650 W, the spot size was 2,5 mm, the step size was 1,2-1.3 mm, the head speed was 0.05 m/s. The surface layer microstructure of Stellite 6 alloy after LHT is shown in figure 1.

The hardness test was performed using TR-5006 hardness tester with a diamond cone indenter. 3 measurements were performed in different parts of each alloy sample. The results are shown in table 1.

Table 1. Hardness measurement results.

Alloy	Hardness, HRC
Stellite 6	40; 41,5; 42
Stellite 6 (LHT)	42; 43; 42,5

The microhardness was measured with the help of PMT-3 microhardness tester. The phase composition of Stellite 6 alloy consists of a cobalt matrix (γ -phase), Cr-Co intermetallic compound (σ -phase) and carbides Cr_{23}C_6 and Cr_6C . The results are shown in table 2.

Table 2. Microhardness measurement results.

Phase	Stellite 6, MPa	Stellite 6 after LHT, MPa
γ -phase	8 052	8 320
σ - phase	13 225	13 677
Cr_{23}C_6	17 100	17 865
Cr_6C	20 945	21 519

According to [2], the wear resistance of cobalt alloys increases with an increase in alloy hardness. A decrease in carbide grain size increases alloy hardness. However, experiments showed that substantial hardness increase does not occur after LHT despite the significant grain refinement.

2. Wear on fixed abrasive

The study of fixed abrasive wear was performed using a specialized machine, whose main feature is that during each operating cycle all surface points of the sample pass an equal distance and are also constantly in contact with the fresh surface of the abrasive.

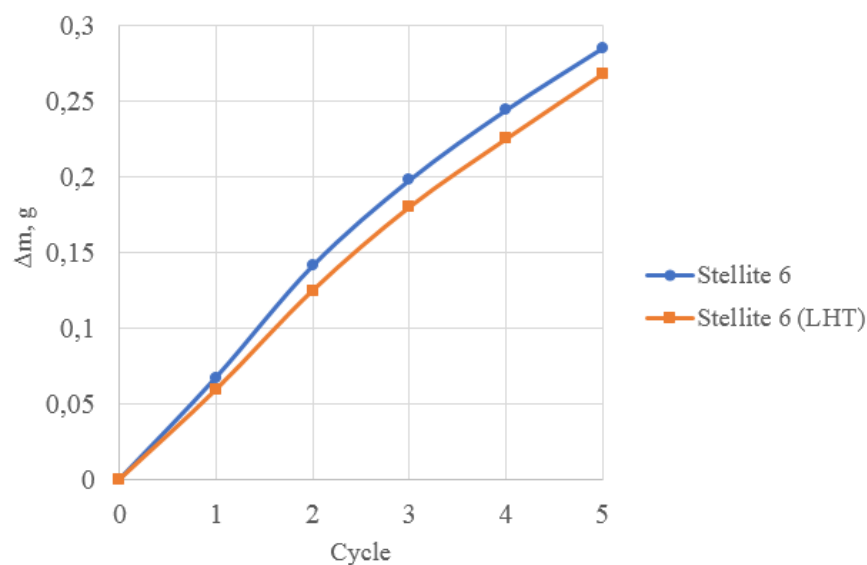


Figure 2. Fixed abrasive wear.

This is achieved by the fact that the fixed on the holder test sample moves in reciprocating motion, while the sandpaper moves stepwise perpendicular to the direction of its motion. During the test each sample went through 5 cycles, the length of each cycle was 50 meters. The sandpaper made of silicon carbide grade 54C with the grain size of 100 microns was used as an abrasive. Wear resistance was evaluated on the weight loss of the sample.

The test results show that laser heat treatment does not have a noticeable effect on the fixed abrasive wear volume. This is due to the fact that upon the contact of the abrasive material with the sample surface wear occurs through the micro-cutting mechanism. The cobalt matrix, large and small carbides are equally separated from the surface. Grinding of carbides cannot therefore significantly affect this process.

3. Shock-abrasive wear

Evaluation of the wear resistance of the samples during shock-abrasive wear was performed using the device with acceleration of the abrasive material in the gas stream according to the method [2]. Before testing, the sample was weighed on an analytical balance, and then fixed in the apparatus at various angles α (15°, 30°, 45°, 60°, 90°). The abrasive was supplied using compressed air blown through a nozzle mounted opposite the sample at the distance of 200 mm. The flow velocity of the abrasive particles was 70-80 m/s; silicon carbide with a particle size of 0,2-0,315 mm was used as an abrasive. Wear resistance was also evaluated on weight loss of the sample.

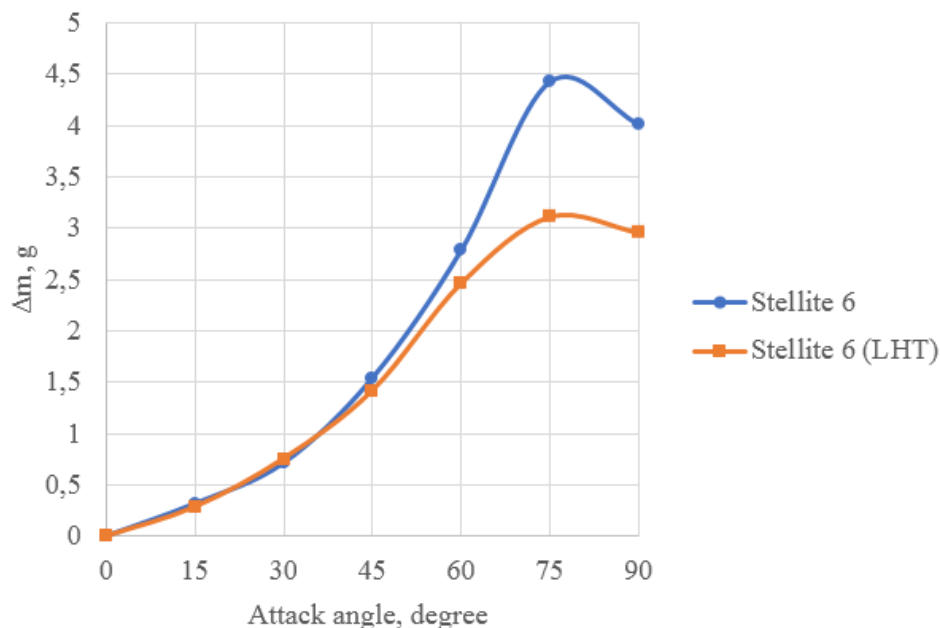


Figure 3. Gas-abrasive wear.

The results show that there is no noticeable difference between the wear of the samples at small angles of attack ($\alpha=15-30^\circ$) and the fixed abrasive wear. As the angle of attack increases, along with micro-cutting, a shock effect becomes noticeable, which leads to the destruction of brittle (solid) phases (carbides and intermetallic compounds). The maximum wear is observed at the angle of attack of $\sim 75^\circ$. At the angle of attack close to 90° , the microcut becomes less noticeable and the destruction of the samples occurs mainly due to the impact loads. In carbides, the hardest structural components of the alloy, microcracks are formed under the influence of shock loads, which lead to their destruction. The lower wear of the sample with LHT is explained by the fact that the shock impulse from the abrasive particle is distributed equally among many small carbides, in contrast to the sample without additional processing.

4. Metal-to-metal friction wear

To determine the wear resistance during metal-to-metal friction testing machine SMTS-2 was used, which allows to test materials for wear and determine their antifriction properties during sliding friction and rolling friction at normal temperatures using pairs of samples: disk-disk, disk-block, sleeve-shaft [3]. Cylindrical samples from Stellite 3 alloy with the hardness of 51 HRC were used as a counterbody. As in the previous cases, the wear resistance evaluation was performed on sample weight change. The wear test results of the samples and the total wear of the sleeve-shaft pair are shown in figures 4a and b, respectively.

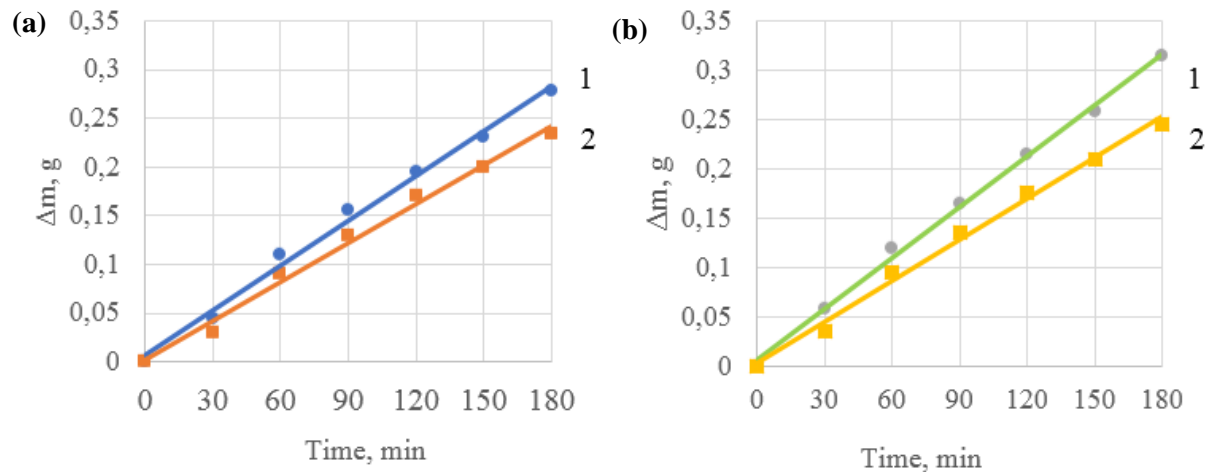


Figure 4. Metal-to-metal friction wear (a): 1 – Stellite 6, 2 – Stellite 6 (LHT); The total wear of the sleeve-shaft pair during metal-metal friction (b): 1 – Stellite 6-Stellite 3; 2 – Stellite 6 (LHT)-Stellite 3.

During friction metal on metal without abrasive the sample without LHT has a greater wear, which is explained by the destruction of large fragile structural components. At the same time the total wear of the Stellite 6 - Stellite 3 pair was significantly higher than that of the sample with LHT.

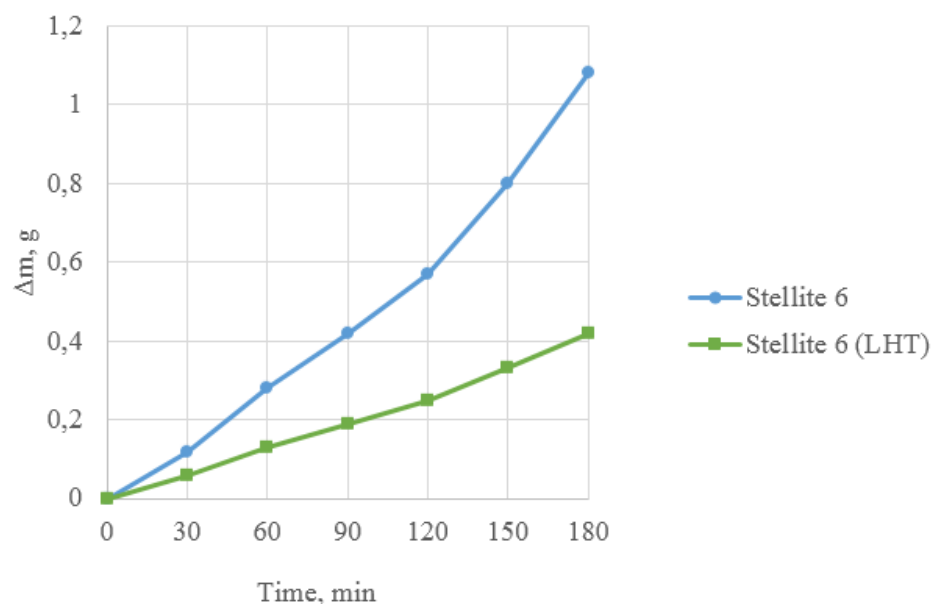


Figure 5. The total wear of the sleeve-shaft pair during friction metal-metal with an abrasive.

With the gradual wear of the soft cobalt matrix of the alloy, large carbides in the Stellite 6 alloy have a strong scratching effect on the material of the counterbody, thereby wearing it out more strongly in comparison with the smaller carbides obtained in the Stellite 6 sample after LHT.

Noticeable difference in the degree of the wear of the samples is observed when an abrasive, silicon carbide with fraction of 0.2-0.315 mm, is added to the contact surface (figure 5). This is explained by the implantation of abrasive particles in a soft cobalt matrix Stellite 6 alloy sample without heat treatment, while the dense fine structure of the sample with LHT prevents the introduction of abrasive particles in the metal matrix.

5. Conclusion

The experiments showed that the use of laser heat treatment for parts made of Stellite 6 alloy allows to significantly increase their wear resistance under shock-abrasive wear and when working under friction of metal on metal in an abrasive medium.

References

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